Fuel Cell Mobile Electric Power

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Rob Privette

Babcock & Wilcox

(330) 829-7370

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Agenda

- Overview of fuel cell technology
- DARPA / Army Mobile Electric Power Program
- Mobile fuel cell system power conditioning

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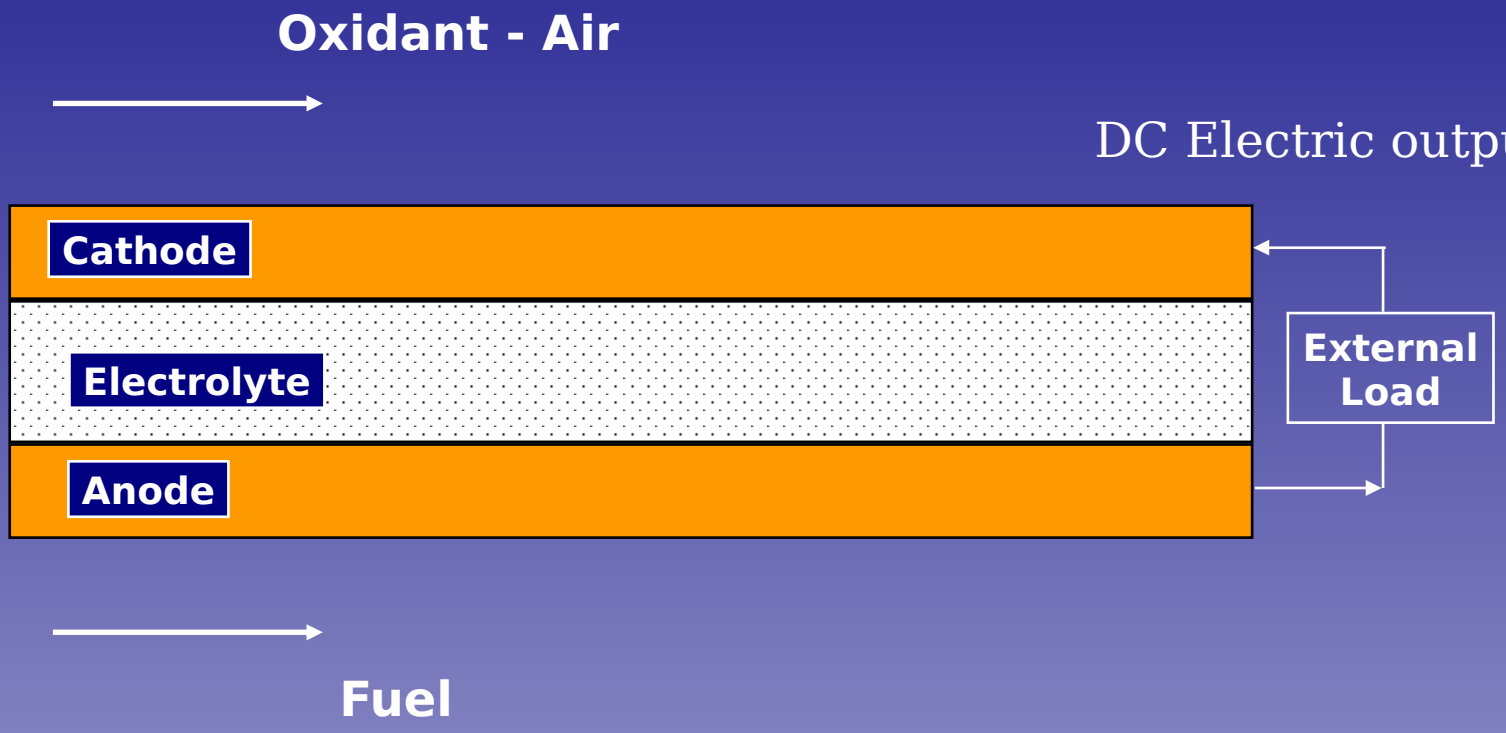
Fuel Cell Operating Principal



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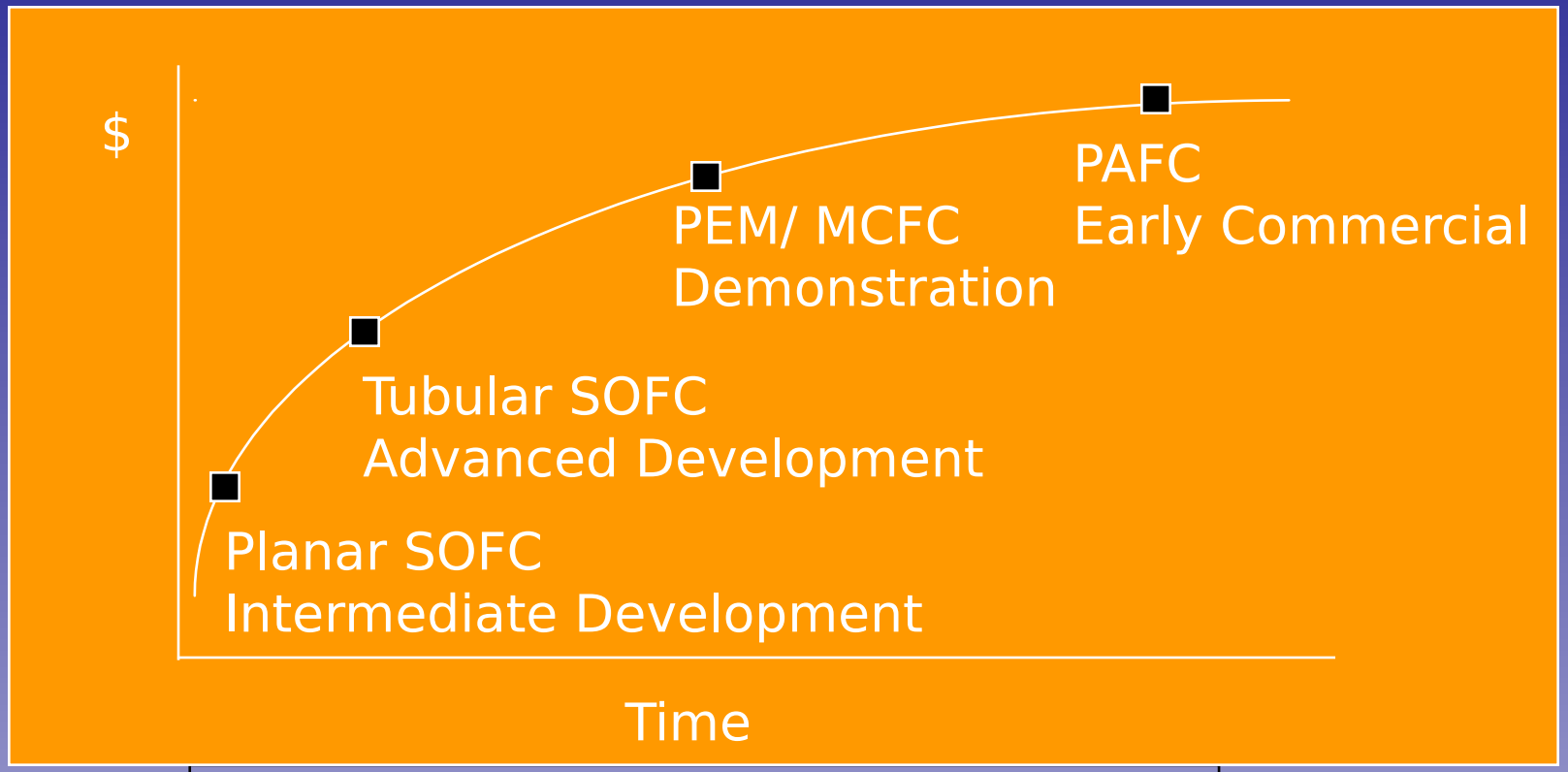
Fuel Cell Development Expenditures



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Attributes of Fuel Cells

	AFC	PAFC	PEMFC	MCFC	SOFC
Electrolyte	KOH	Phosphoric Acid	Sulfonic Acid Polymer	Molten Carbonate Salt	Yittria stabilized Zirconia
Temperature	100 C	200 C	100 C	650 C	850 C
Fuel	H_2	H_2	H_2	H_2/CO	H_2/CO
FC Efficiency (H_2 fuel)	60%	55%	60%	55%	55%
Power Density	<5 kW / ft^3	~3 kW / ft^3	~40 kW / ft^3	<5 kW / ft^3	~30 kW / ft^3
Cell Life	5 yrs	5 yrs	5 yrs	3 yrs	5 yrs
Start-up	Fast	Moderate	Fast	Moderate	Slow

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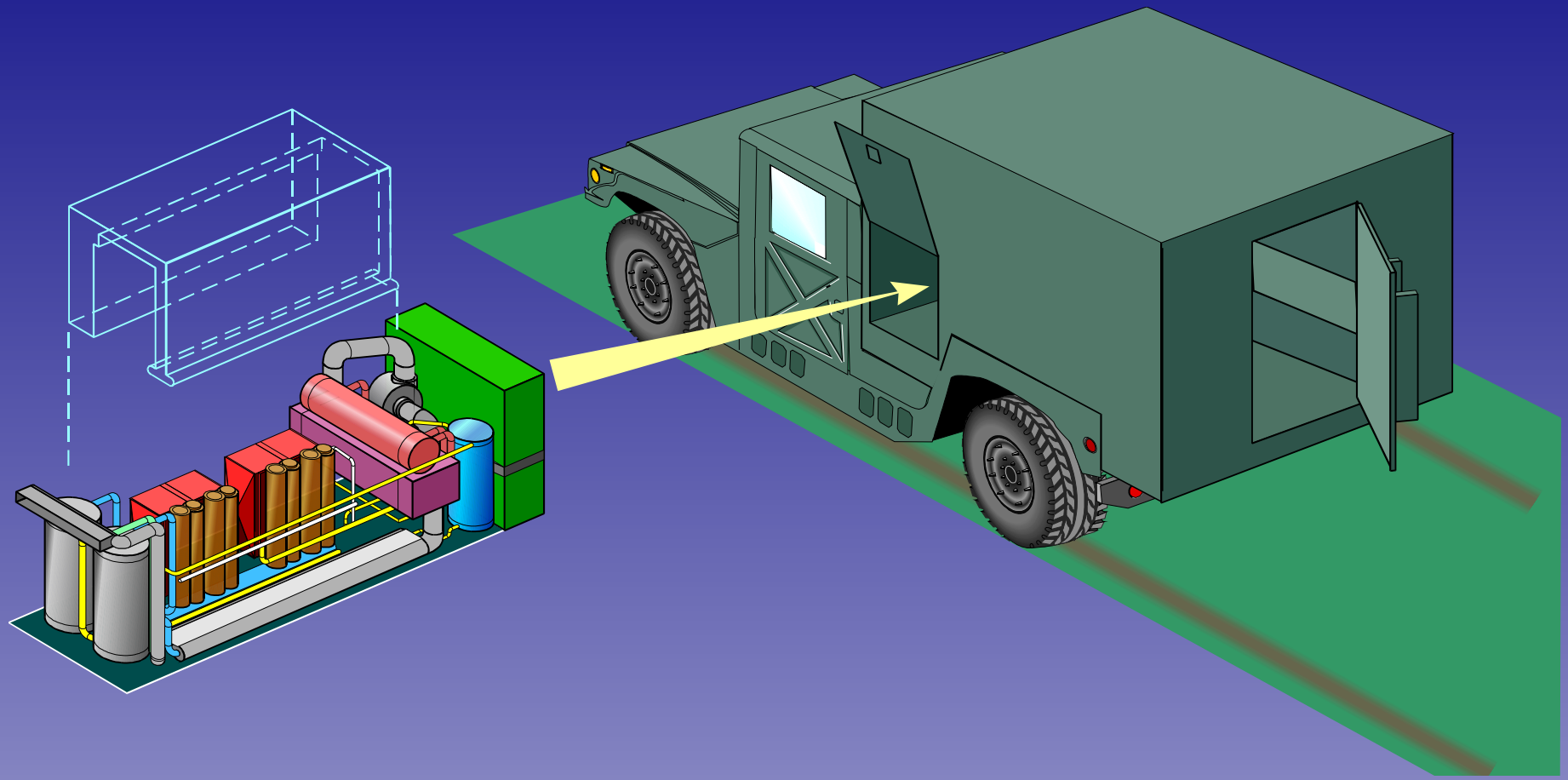
MEP Generator Program



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MEP Program Description

- Four-year program sponsored by DARPA and U.S. Army Research Office
- Application
  - 10 kWe mobile generator for Army Lightweight Multipurpose Shelter
- Key project elements
  - Compact, lightweight system for mobile applications
  - Fuel processor development (JP-8, DF-2)
  - Power system integration with SOFCs
  - Demonstration of 5 – 10 kW SOFC power system

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DARPA / Army MEP Generator

Program to demonstrate a multi-kWe planar SOFC mobile electric power generator using DOD logistics fuel

- **Phase 1: Developed preliminary system design based on steam reforming (complete)**
- **Phase 2: Demonstrated logistics-fueled SOFC MEP breadboard system (complete)**
- **Phase 3: Demonstrate a multi-kW integrated SOFC MEP generator. Design a prototype 10 kW SOFC generator (in-progress)**

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MEP System Test Facility

B&W Research Center, Alliance, Ohio

Purpose:

- Long-term integrated system testing
- Prototype product development

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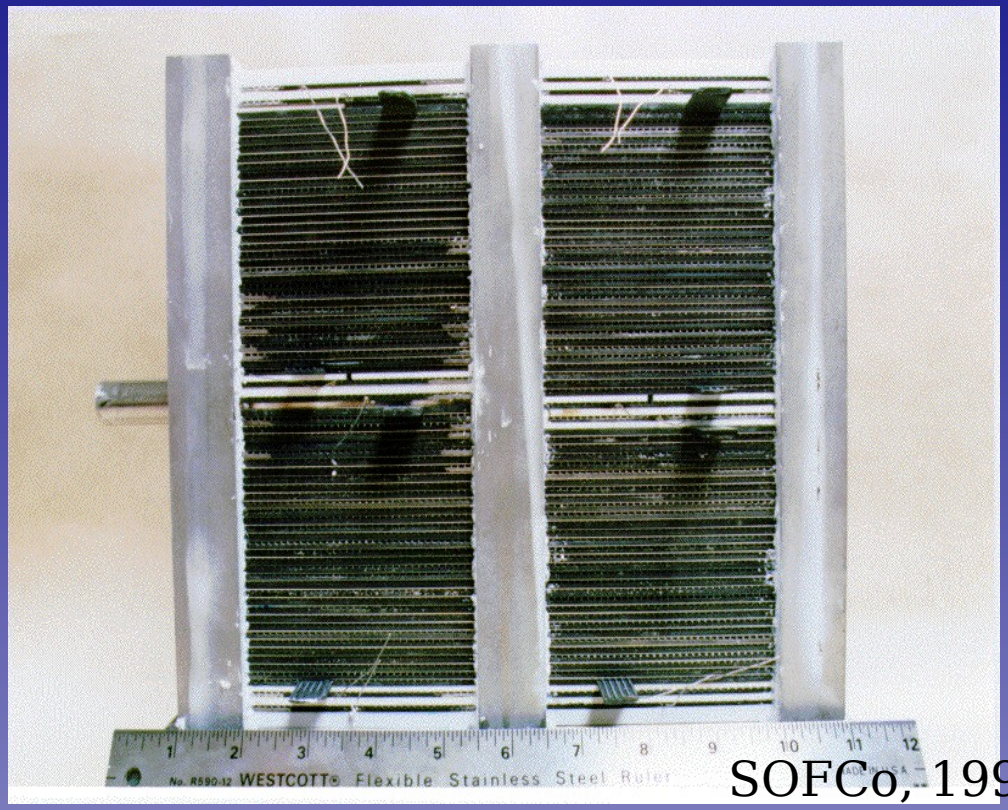
SOFCo Patented CPn Design

- Staged oxidation provides enhanced electrical efficiency
- New manifold design provides improved fuel utilization
- kW-Class stack demonstrations



SOFCo, 199

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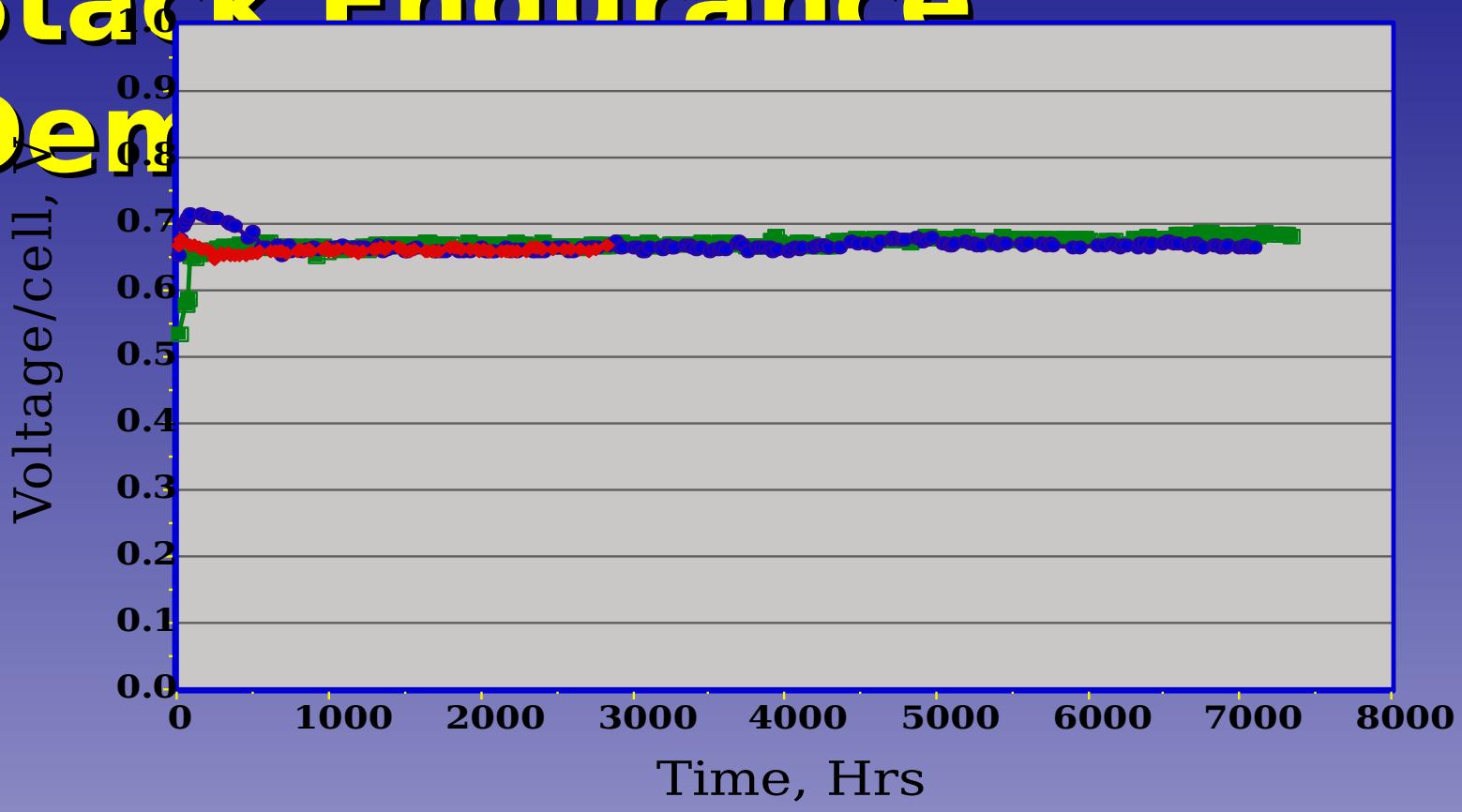
Multi-Thousand Hour Stack Endurance Dem



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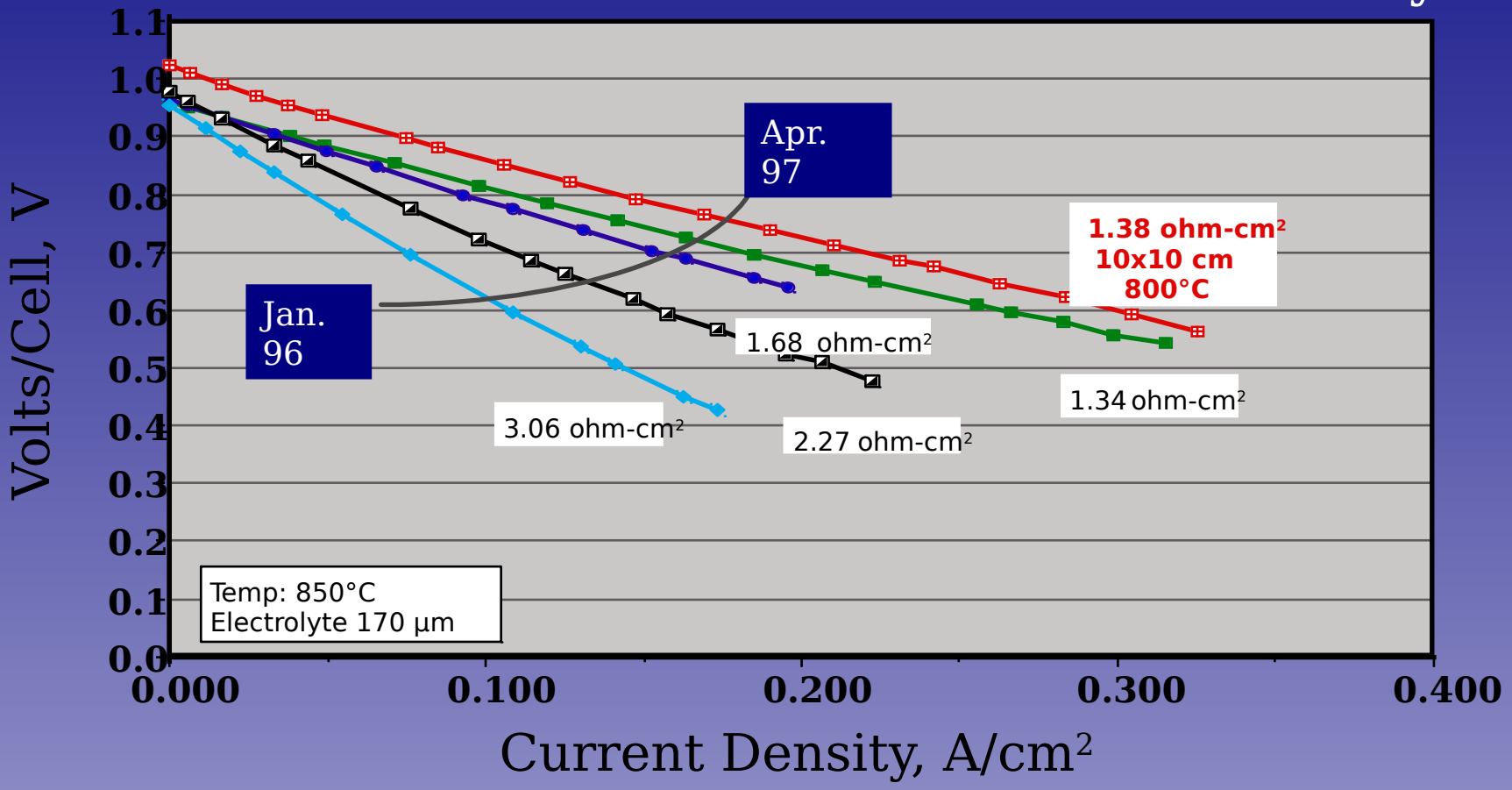
Stack Performance

Stack Performance doubled in the last year



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MEP Accomplishments

- Phase 1 (complete) Developed layout for Army MEP, Demonstrated bench-scale sulfur-tolerant steam reforming
- Phase 2 of (complete) Demonstrated integrated system JP-8 fuel processor and fuel cells,

  Demonstrated conversion of JP-8 to hydrogen-rich gas for 400 hrs using compact 10 kWe partial oxidation fuel processor

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MEP Phase 3

- Technology Readiness Demonstration (9/97)
  - Continuous operation of 10 kWe JP-8 fuel processor for 100+ hrs
  - x100 hr operation with on-line maintenance
  - Fuel conversion efficiency of 75% (HHV)
- Multi-kW Generator Demonstration (Aug '98)
  - Net system efficiency >30%
  - Transient and load following operation

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Mobile fuel cell system power conditioning

- DC/ AC Conversion
  - Army application requires
    - 10 kW AC at 0.8 power factor
    - 60 Hz AC at 120 V 1-Phase and 240 V 1-Phase, 3-wire
  - Fuel cell module configured for 50 VDC
- Dual Fuel Cell/ Battery Source
  - Start-up, Back-up
  - Peaking service

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Mobile fuel cell system power conditioning (Cont)

- Electrical loads
  - Motors, Generators, Motor drives
  - Actuators/ Actuator drives
  - Energy storage

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Mobile fuel cell system power conditioning (Cont)

- Steady-state electric output
  - Frequency variation:
    - 2% bandwidth over 30 sec, 3% over 4 hour
  - Voltage variation under load
    - Less than 2% over 30 sec, 3% over 4 hr
  - Waveform deviation factor
    - Less than 6%
  - Individual harmonic deviation factor
    - Less than 3%

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Mobile fuel cell system power conditioning (Cont)

- Transient electric output
  - Recovery from application of rated load
    - Less than 20% reduction in voltage
    - Less than 3% reduction in desired frequency
    - Less than 3 seconds
  - Recovery from rejection of rated load
  - Application of motor load
    - Less than 35% decrease in voltage
    - Less than 5 seconds

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Mobile fuel cell system power conditioning (Cont)

- Physical
  - Volume - 10 kW/ ft^3
  - Weight - 0.5 kW/ lb
- Environment
  - Thermal
  - Shock

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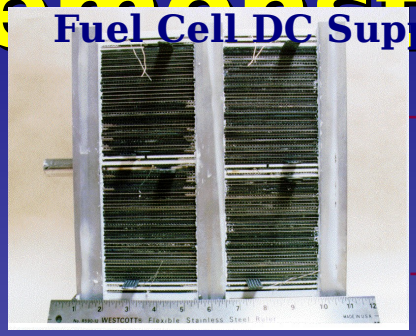
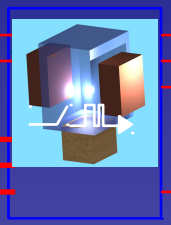
Fuel Cell/ PEBB Demonstration





PEBB Demonstrator

60Hz Inverter
400 Hz Inverter

60Hz Motor Control
400Hz Motor Control
DC Motor Controller
3 Phase Rotary Actuator
Single Phase Linear Actuator

DC to DC Buck Converter
DC to DC Boost Converter

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